Advanced timing of spring mixed layer development in recent Oyashio region

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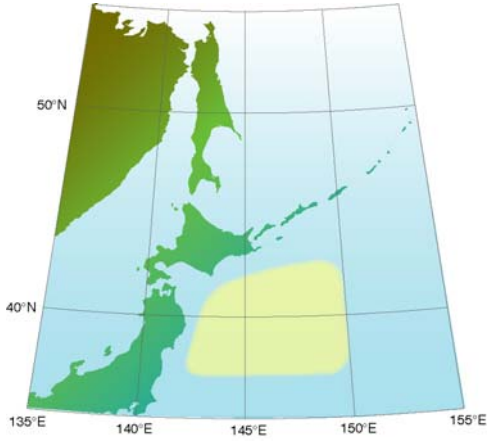
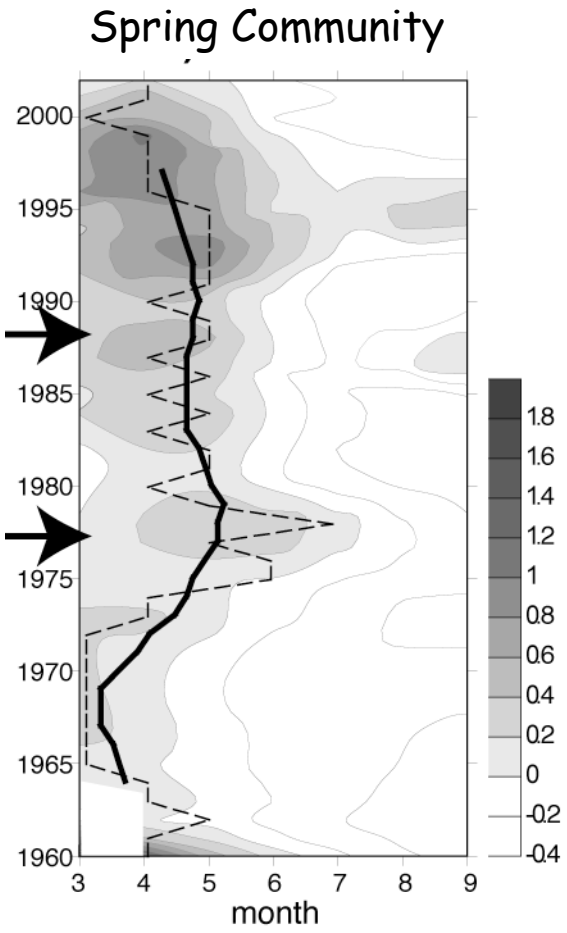
Inter-annual variation in the peak-timing of
Spring-Copepod community in Oyashio region

[Chiba et al., 2006, GCB]

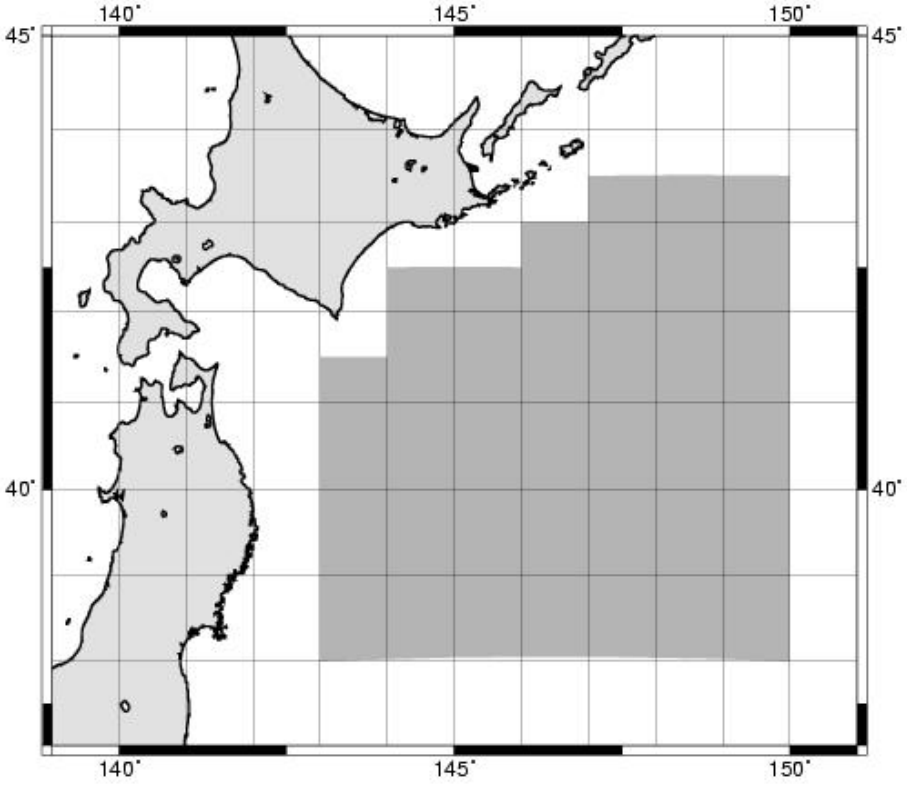




temporal variation of zoopl. phenology indicates that there should be any temporal variation in the hydrographic seasonality, e,g, seasonal MLD development

data

- hydrographic data (vertical T, S data) from two on-line data bases was used
  JODC data base (http://www.jodc.go.jp/index_e.html)
  A-line data base(http://hnf.fra.affrc.go.jp/a-line/)
- 1970-2008, Apr.1 - May 20
- open North Pacific, 38N-43.5N, 143E-150E
- near-coastal data were eliminated
- Oyashio data were extracted based on T<5^{o}C at 100m
  (1743 data in total)



*obtained data are then divided into the following 10-day seasonal subset.

Early April [Apr.1 -Apr.10]
Mid April [Apr.11 -Apr.20]
Late April [Apr.21 -Apr.30]
Early May [May 1 -May10]
Mid May [May11-May20]

analysis

- density difference from 0m and each reference depth ($\Delta\sigma_T$[x], x =30m, 50m, and 75m) was calculated.

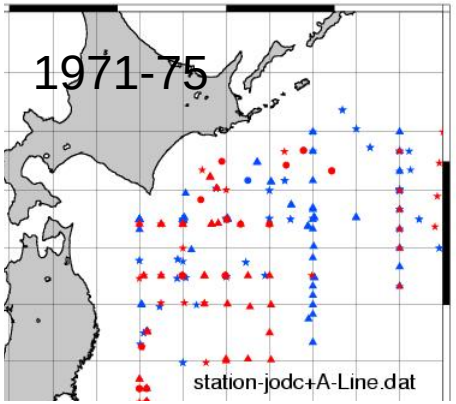
- percentage of the station with $\Delta\sigma_T$[x] >0.125 was calculated for each X in each 5-year interval in each 10-days seasonal subset.

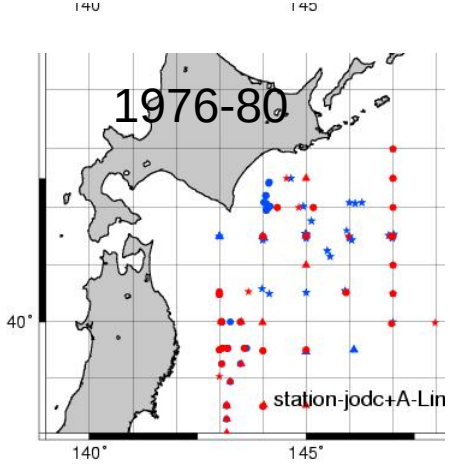
Year band	1970-75	1976-80	1981-85	1986-90	1991-95	1996-00	2000-05
Early Apr.							
Mid Apr.							
Late Apr.							
Early May							
Mid May							

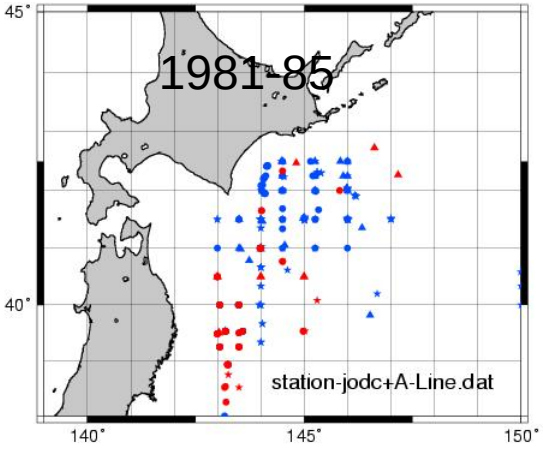
*if only less than 10 $\Delta\sigma_T$[x] data were available for a 5-y x 10-day parcels,, we eliminated statistical calculations for that percerl.

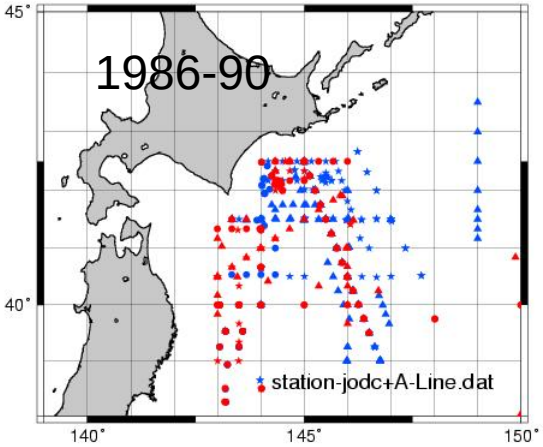
data distributions

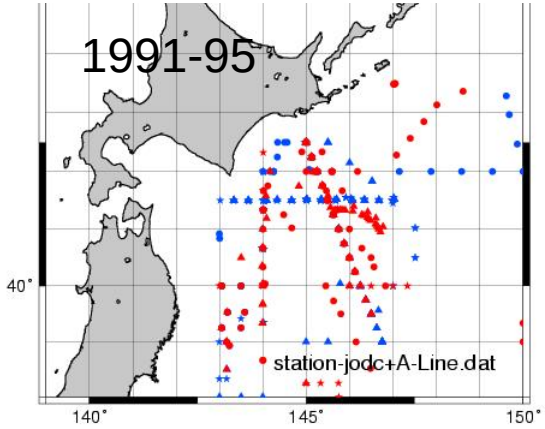
○early-
△mid-
★Late-
Apr.(Blue)
May (red)

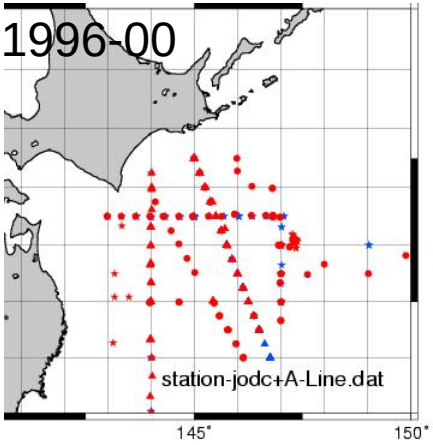


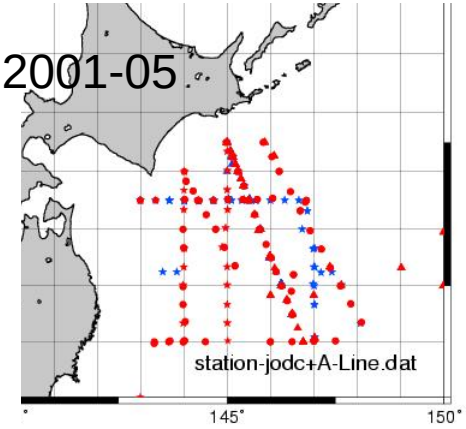






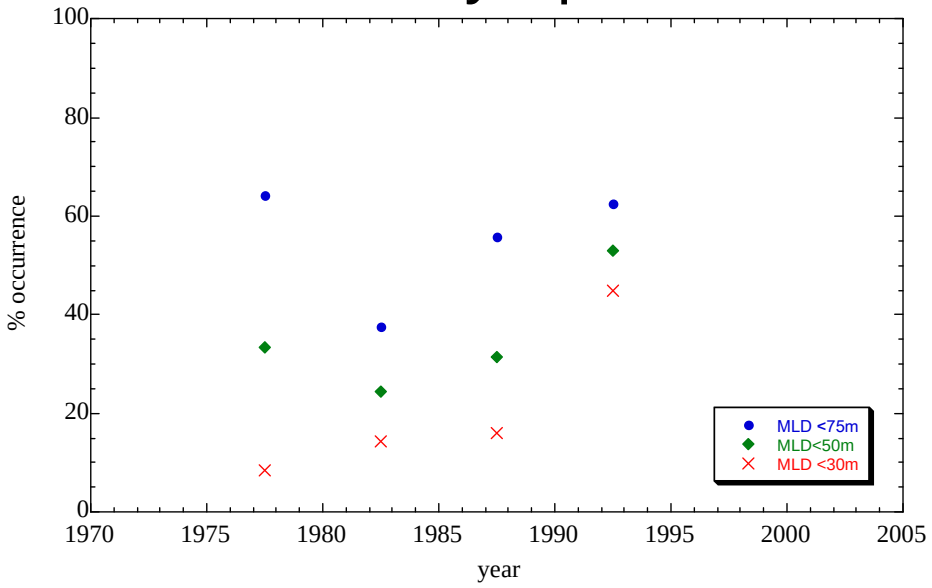




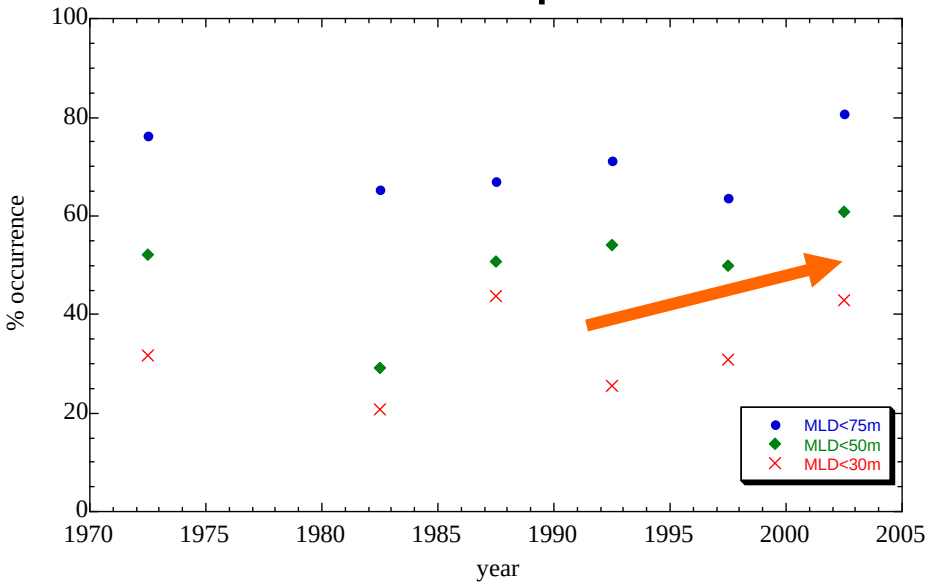


Result (1): time series of MLD % occurrence

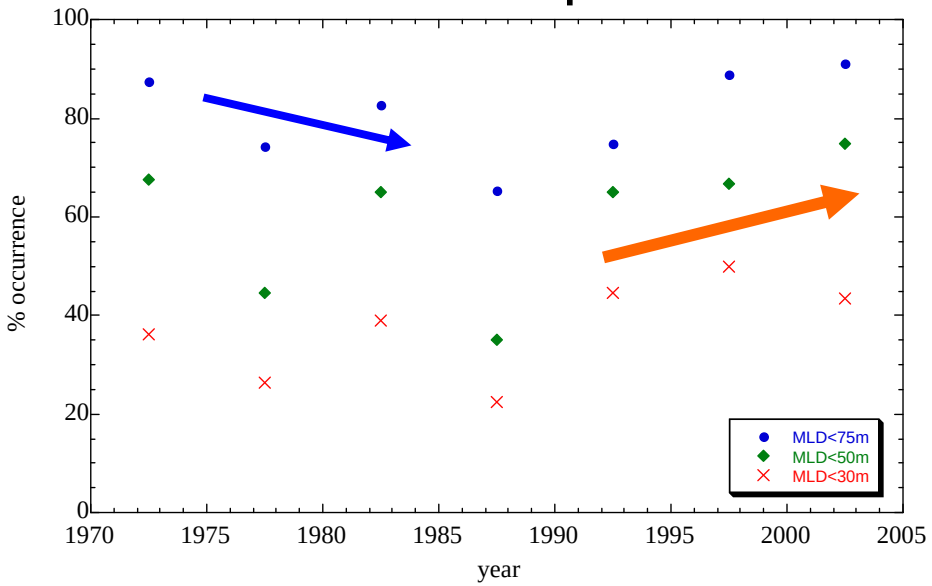
Early Apr.



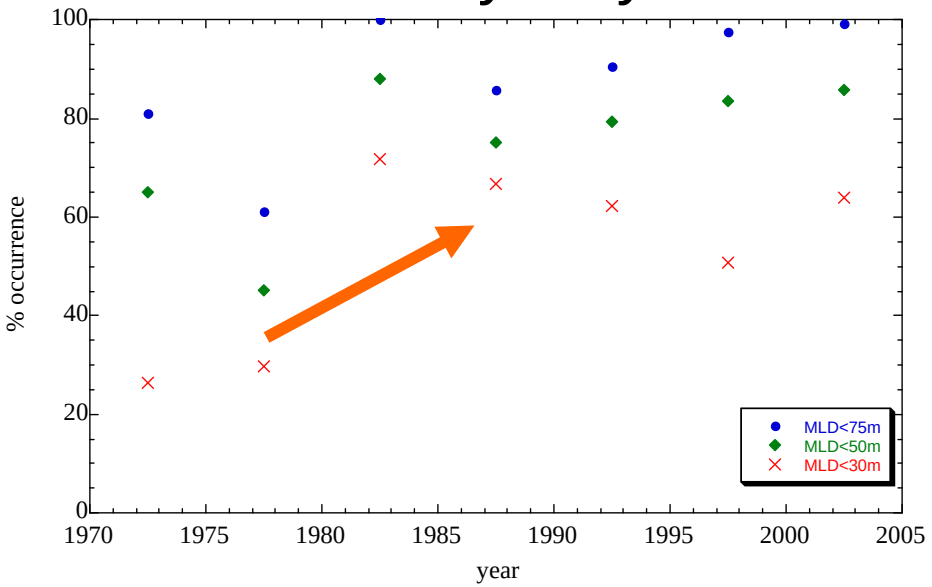
Mid Apr.



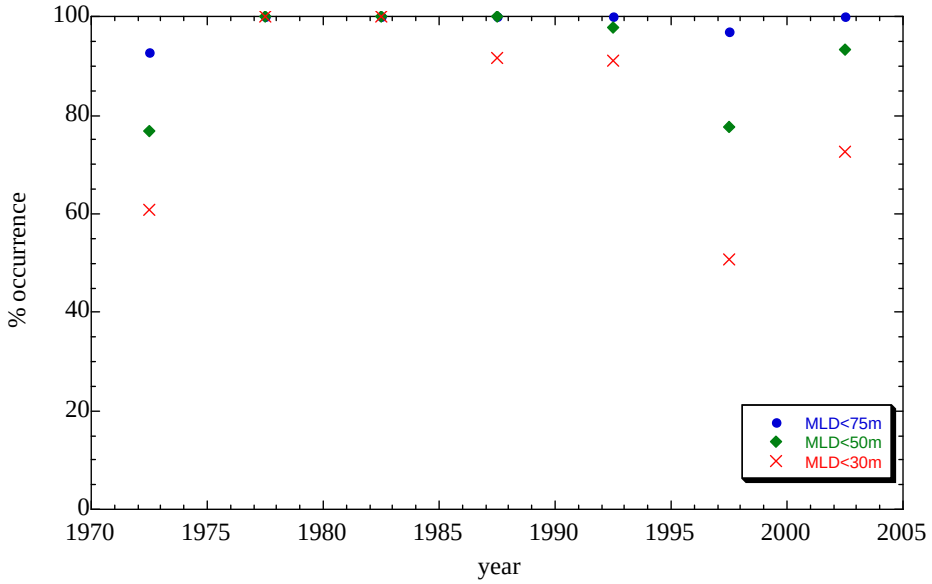
Late Apr.

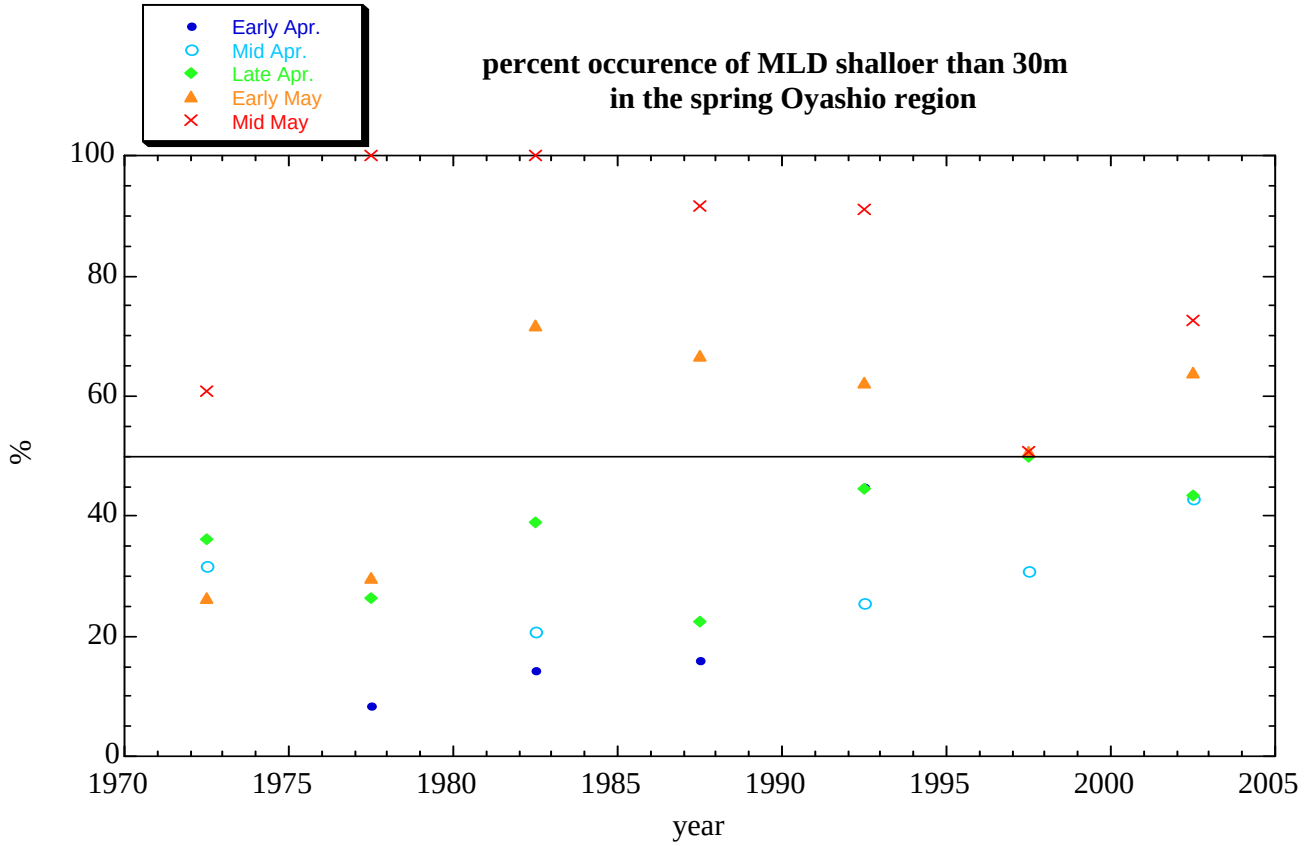


Early May



Mid May





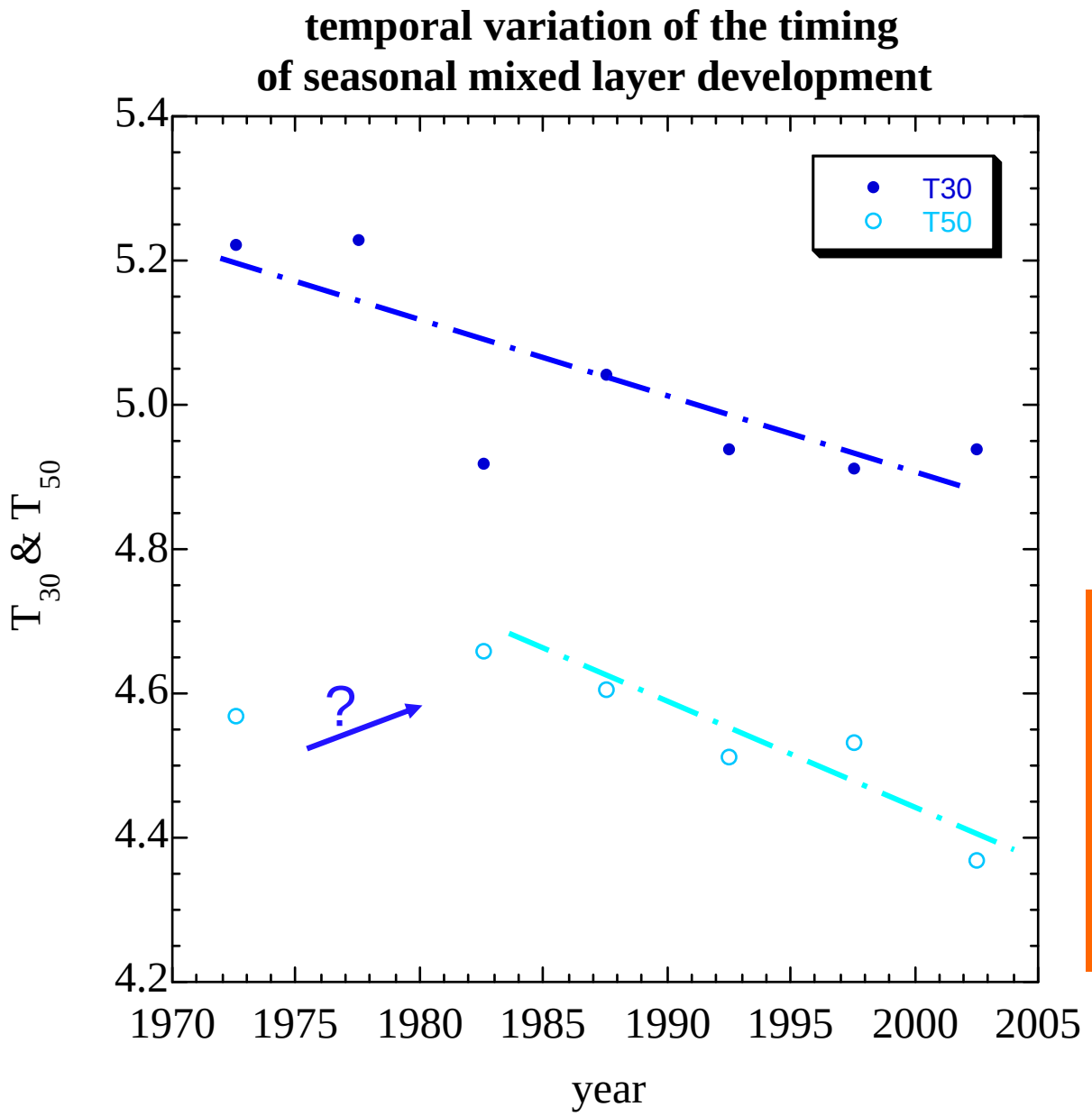
Expected date at which >50% of the Oyashio region has MLD shallower than 30m (T^{30}) can be calculated from the above data as:

$$T^{30} = T_{i-1} + [T_i - T_{i-1}] * [50 - m^{30}_{i-1}]/[m^{30}_i - m^{30}_{i-1}]$$

*m^{30}_i ; observed % occurrence of $\Delta\sigma_T[30] > 0.125$ at seasonal subset i

*T_i ; average observation date of the data used at seasonal subset i

Result (2): time series of MLD deveropment timing (T^{30} and T^{50})



T^{30}: significant advance between late-70s and early-80s

T^{50}: gradual advancement after 1980

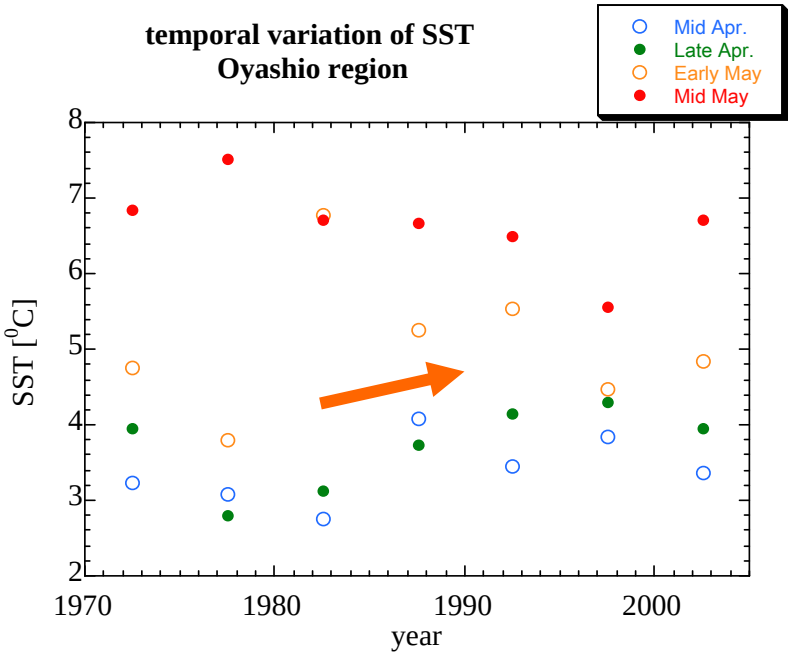
*slight delay from 1970s to early-80s...?

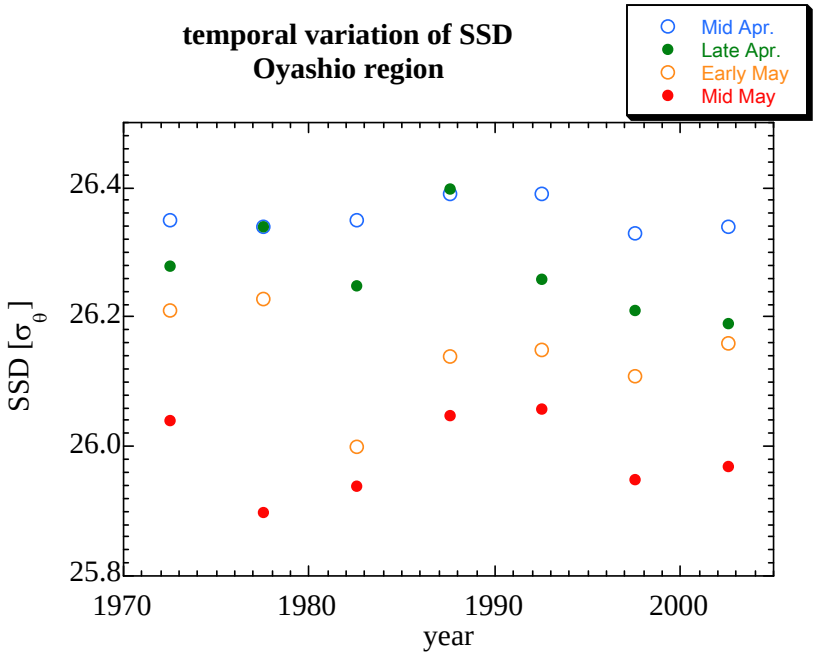
At all events, enhancement of MLD development timing during 1970 - 2005 is observed as:

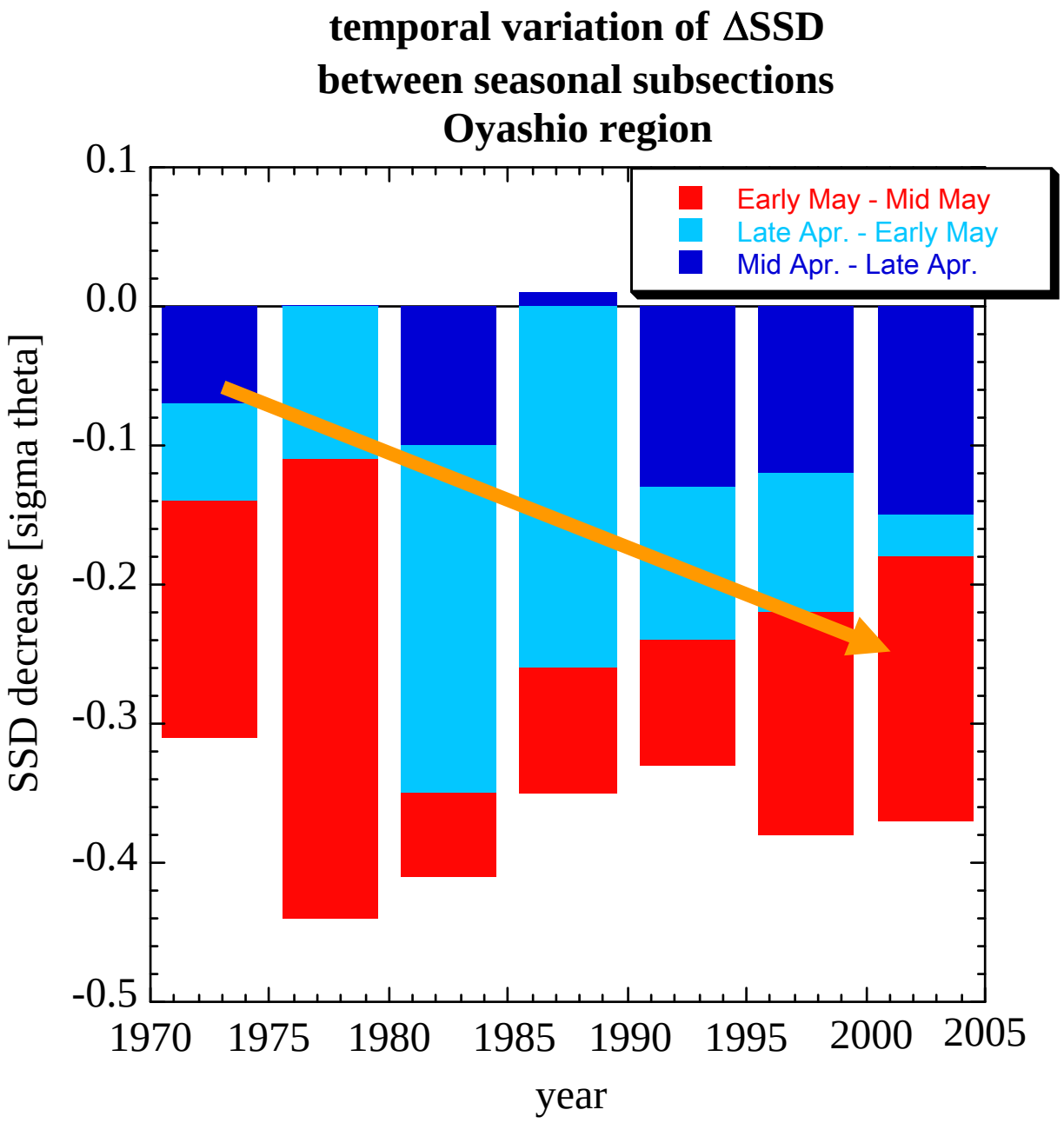
T^{30}: ~9 days (5.2 =>4.9)

T^{50}: ~6 days (4.6 =>4.4)

what is the cause of MLD-development advance?






temporal variation of ΔSSD
between seasonal subsections
Oyashio region
Early May - Mid May
Late Apr. - Early May
Mid Apr. - Late Apr.
SSD decrease [sigma theta]
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
1970
1975
1980
1985
1990
1995
2000
2005
year

conclusion

Based on the temporal variation analysis of MLD development timing,
it is found:

1] During the years from 1970 to 2005, average timing of spring MLD development with MLD = 50m (T^{50}) has been advanced by 6 days, and that with MLD = 30m (T^{30}) has been advanced by 9 days.

2] The cause of advancement is so far unclear, but it seems to be related to:
#inter-annual increase of the spring Oyashio SST
#corresponding advance of seasonal SSD descend during the April.

3]Observed temporal variation of T^{50} and T^{30} did not exactly correlates with the formerly-observed biological phenology changes [e.g., Zoopl. abundance peak timing, Chiba et al., 2006]. Temporal variations of many other hydrographic seasonality characters to understand complicated physical-biological couplings in the phenology changes,